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Title:

METHOD OF MANUFACTURING CERAMIC ARTIFICIAL TOOTH RESTORATIONS.

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Inventor(s): ODEN AGNETA (SE)

Applicant(s): NOBELPHARMA AB (SE); SANDVIK AB (SE)

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ABSTRACT:

The present invention relates to a method of manufacturing artificial tooth restorations for natural teeth or implants comprising a ceramic densely sintered, high strength individual core (B) with dental porcelain (A) by powder metallurgical manufacturing methods. The inner surface (I) of the core (B), which will fit against one or more prepared tooth surfaces (P) or artificial abutments, are manufactured by forming a ceramic powder mixture against a surface of a body at which this mentioned surface is manufactured by registering the surfaces of the prepared teeth or artificial abutments and their mutual relationship with a three dimensional optical or mechanical reading method directly in the mouth or on a model in e.g. plaster after which the registered surfaces are reproduced in an enlarged size e.g. with a computer controlled milling machine at which the enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and considering the gap for cement.



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(71) Applicant : **SANDVIK AKTIEBOLAG**  
S-811 81 Sandviken 1 (SE)

(71) Applicant : **Nobelpharma AB**  
Box 5190  
S-402 26 Göteborg (SE)

(72) Inventor : **Oden, Agneta**  
Bergstigen 26  
S-182 74 Stocksund (SE)

(74) Representative : **Östlund, Alf Olof Anders et al**  
Sandvik AB Patent Department  
S-811 81 Sandviken (SE)

(54) Method of manufacturing ceramic artificial tooth restorations.

(57) The present invention relates to a method of manufacturing artificial tooth restorations for natural teeth or implants comprising a ceramic densely sintered, high strength individual core (B) with dental porcelain (A) by powder metallurgical manufacturing methods. The inner surface (I) of the core (B), which will fit against one or more prepared tooth surfaces (P) or artificial abutments, are manufactured by forming a ceramic powder mixture against a surface of a body at which this mentioned surface is manufactured by registering the surfaces of the prepared teeth or artificial abutments and their mutual relationship with a three dimensional optical or mechanical reading method directly in the mouth or on a model in e.g. plaster after which the registered surfaces are reproduced in an enlarged size e.g. with a computer controlled milling machine at which the enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and considering the gap for cement.

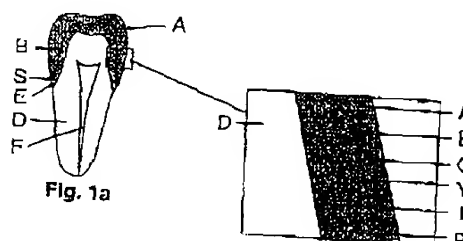


Fig. 1a

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This invention relates to powder metallurgical manufacturing methods for making accurately shaped artificial tooth restorations with an individually manufactured core of a densely sintered, high strength ceramic material, which fits against prepared tooth surfaces or artificial abutments. On these cores dental porcelain can be fired to tooth crowns, inlays, veneers or bridges.

U.S. 5,080,589 discloses a method of manufacturing copings in densely sintered, high strength ceramic material where the sintering shrinkage is considered. According to this patent the copings are premanufactured, which means that they have in advance given measure.

U.S. 5,106,303 and the Swedish patent SE 469 057 disclose manufacturing of inlays, onlay crowns and veneers in densely sintered, high strength ceramic material by copy milling a green body or a presintered or sintered body from an impression of the prepared tooth surface and considering the sintering shrinkage.

The object of the present invention is to provide a rational manufacturing technique for manufacturing tooth crowns, inlays, veneers or bridges in densely sintered, high strength ceramic material by using modern powder metallurgical technique and reading technique.

The present invention relates to a method of manufacturing with powder metallurgical methods artificial tooth restorations for natural tooth or implants containing an individual core in densely sintered, high strength ceramic material with dental porcelain fired to the surface. The inner surface of the core, which will fit to one or more prepared surfaces or artificial abutments is manufactured by forming a ceramic powder mixture against a surface of a body at which mentioned surface is manufactured by a three dimensional optical or mechanical reading method, register the prepared surfaces of the prepared tooth or artificial abutments and their mutual relationship, either directly in the mouth or on a model in e.g. plaster after which the registered surfaces are reproduced in an enlarged size e.g. by using a computer controlled milling machine at which the enlargement is calculated by considering the shrinkage of the ceramic material during the sintering to full density with the addition of a desired gap for cement.

Fig. 1 shows cross sections of natural teeth one with an artificial tooth crown (Fig. 1a) one with an inlay (Fig. 1b), and one with a veneer (Fig. 1c). In this figure A= dental porcelain, B= core in densely sintered ceramic, Y= the outer surface of the core, I= the inner surface of the core, C= cement, P= the prepared surface of the tooth, S= the preparation border, E= enamel, D= dentin and F= pulp.

Fig. 2 shows a cross section of a bridge, which is cemented on two supporting teeth. These supporting teeth can have a vital abutment (U<sub>1</sub>) or an artificial

abutment (U<sub>2</sub>) manufactured in a dental alloy, ceramic material or a strengthened polymer. The bridge in Fig. 2 contains two artificial dental crowns according to Fig. 1a and with a pontic (V) between as replacement for a lost tooth. The bridge contains a core (B) with dental porcelain (A). A bridge can contain more supporting teeth and also more pontics in between. The supporting teeth can also be prepared for inlays or veneers. Veneers can be made both buccally and lingually. The supporting teeth can also be implants with artificial abutments.

Fig. 3 shows a cross section of an example of a press for individual cores for tooth crowns. K<sub>1</sub> is a model of a preparation for a tooth crown enlarged considering the sintering shrinkage. S is the preparation border, T the top of the model, R its bottom and L the surface, which is the enlarged surface of the preparation (P). K<sub>2</sub> consists of K<sub>1</sub> with a coping of e.g. wax and Z is the outer surface of this coping. F is a tube. G<sub>1</sub> is a plate with a cylinder G, which fits into F. H is a cylinder, which also fits into F. H, F, E, G and G<sub>1</sub> can be made in e.g. metallic material E is made in a viscous elastic material as well as J and X, which are impressions of K<sub>2</sub>. M is a cavity with space for ceramic powder. K<sub>1</sub> has been placed in X and P<sub>1</sub> is the force with which H is pressed against G.

Fig. 4 shows a cross section of an impression of two supporting teeth prepared for crowns and the gingiva between the teeth. c<sub>1</sub> and c<sub>2</sub> are the impressions of the preparations of the supporting teeth in a, which is the impression material. b<sub>1</sub> and b<sub>2</sub> are two parallel tubes firmly united to each other with b<sub>3</sub>. The inner surfaces of b<sub>1</sub> and b<sub>2</sub> consist of two cylinder surfaces with radii r<sub>1</sub> and r<sub>2</sub>. They are connected with e<sub>1</sub>-e<sub>2</sub>, w is the angle between the parts of b<sub>1</sub> and b<sub>2</sub> with radius r<sub>1</sub> and the surface with the cross section e<sub>1</sub>-e<sub>2</sub>. q<sub>1</sub> and q<sub>2</sub> are grooves in the part of the tubes b<sub>1</sub> and b<sub>2</sub> with radius r<sub>2</sub>. h is the distance between the parallel central axes of b<sub>1</sub> and b<sub>2</sub>. n<sub>1</sub> and n<sub>2</sub> are models of c<sub>1</sub> and c<sub>2</sub> made by pouring model material e.g. plaster in the tubes b<sub>1</sub> and b<sub>2</sub> and c<sub>1</sub> and c<sub>2</sub>.

Fig. 5 shows N<sub>1</sub> and N<sub>2</sub> which are enlarged (compensated for the shrinking during sintering) models of n<sub>1</sub> and n<sub>2</sub>. f is a fixture with the holes g<sub>1</sub> and g<sub>2</sub>, manufactured so that the distance H between the central axes of g<sub>1</sub> and g<sub>2</sub> is h when enlarged considering the sintering shrinkage as well as the inner shape of the holes g<sub>1</sub> and g<sub>2</sub>, which are enlarged from the inner surface of the tubes b<sub>1</sub> and b<sub>2</sub>. Q<sub>1</sub> and Q<sub>2</sub> are the enlarged grooves q<sub>1</sub> and q<sub>2</sub>.

Fig. 6 shows N<sub>1</sub> and N<sub>2</sub> placed in the fixture f. X<sub>1</sub> is a tool made in a rubber material and M<sub>1</sub> is a cavity.

As can be seen from Fig. 1 and Fig. 2 artificial tooth crowns, inlays, veneers or bridges are made as a core in densely sintered ceramic (B) with dental porcelain fired to the surface (A). The tooth restorations are fixed to the prepared surfaces (P) by e.g. cementing, as well as the bridge to the abutments U<sub>1</sub> and U<sub>2</sub>.

The thin layer of cement (C) connects the prepared cavity walls (P) with that part of the surface of the inner surface of the core (I), which has been made so that this surface (D) fits with great precision to the prepared surface (P). On the outer surface (Y) of the core (B) dental porcelain can be fired. The layer of cement can have a thickness  $<100\text{ }\mu\text{m}$ , preferably  $25\text{--}50\text{ }\mu\text{m}$ . The cementing of the restorations can be made with e.g. zinc phosphate cement, glass-ionomer cement or some resin cement. In the last case it can be an advantage to silane treat the inner surfaces (I) of the cores of the constructions, which will be joined with the prepared surfaces (P) of the tooth structure as well as it also can be advantageous to etch and treat the prepared surfaces (P) with a bonding resin before the cementation.

The ceramic powder can be made by several for the expert well known methods. Traditional powder metallurgical technique can be used, where the different components are mixed and ground under dry or wet conditions with water or an inorganic solvent (e.g. alcohols) as grinding liquid. To the ceramic slurry lubricants or other organic binders depending on the choice of forming method are added, when needed at suitable time in the process.

The ceramic base material in the core preferably comprises one or several biocompatible oxides, with additives of carbides and nitrides with or without binders. Examples of biocompatible oxides, which can form base matrix for the ceramic body, are  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{MgO}$ ,  $\text{ZrO}_2$ , and  $\text{ZrO}_2$  with additives of smaller amounts of up to 10 mole-% of  $\text{Y}_2\text{O}_3$  or  $\text{MgO}$  (partly or totally stabilized  $\text{ZrO}_2$ ). Additives can be present as particles with a size of  $<25\text{ }\mu\text{m}$ , preferably  $<10\text{ }\mu\text{m}$  and/or as whiskers (hair shaped single crystals) with a length of  $>10\text{ }\mu\text{m}$ , preferably  $>25\text{ }\mu\text{m}$  and a length to diameter ratio  $>5$ , preferably  $>10$  and/or fibers (polycrystalline) with a diameter  $>10\text{ }\mu\text{m}$  and/or as single crystal platelets with an approximate diameter of  $5\text{--}50\text{ }\mu\text{m}$  and a thickness of  $1\text{--}10\text{ }\mu\text{m}$ . The amount of whiskers, fibers and/or platelets should not exceed 60 volume%.

In a preferred embodiment the ceramic material comprises  $>50\%$   $\text{Al}_2\text{O}_3$  with additives of conventional sintering aids. In order to increase the strength  $<25$  weight %, preferably 3-12 weight % of  $\text{ZrO}_2$ , and/or 5-40 weight %, preferably 10-30 weight % of  $\text{SiC}$ ,  $\text{TiN}$  or  $\text{ZrN}$ -whiskers can be added. It is important that the ceramic material is sintered to closed porosity, which for an oxide material means at least 95% of theoretical density, but in order to ensure good mechanical strength the material should preferably have a density over 98%, densities over 99.5% giving the best strength.

In order to get a suitable colour of the core (B) coloured components can be chosen. Additives e.g. 0.1-1 weight % of  $\text{TiN}$  and/or  $\text{ZrN}$  will give  $\text{Al}_2\text{O}_3$  based cores a faint yellow shade.  $\text{Fe}_2\text{O}_3$  gives a yellow

brown shade and  $\text{MnO}_2$  gives a rose-coloured shade. Of course, additives, which give non-esthetic effects, should not be used.

According to the invention artificial ceramic tooth crowns, inlays, veneers and bridges now exist characterized in that they are made from a ready to press powder with additions of lubricants and/or other organic binders. When manufacturing the core of a individual tooth crown the powder is compacted against the body  $K_1$  to a core, which after sintering to full density fits to the prepared surface and with a desired wall thickness. When manufacturing the enlarged model ( $K_1$ ) the sintering shrinkage has to be considered. The surface (L) must be enlarged in order to have the desired inner geometrical shape (I) of the green body, which fits against the prepared surface (P) after subsequent sintering process. The desired shape of the gap between the tooth crown and the prepared tooth for cementing the crown to the prepared tooth must also be considered. The size of this gap can be calculated e.g. to be as small as possible at the preparation border.

The cores of the tooth crowns are manufactured by cold isostatic compaction, uniaxial pressing, slip casting, pressure casting, injection moulding or by compacting the powder in another way, preferably by a cold isostatic technique against a body ( $K_1$ ), which is shown in Fig. 3.  $K_1$  has a surface (L), which is uniform with the surface (P) of the prepared tooth, on which the tooth crown or the veneer will fit. The body ( $K_1$ ) is manufactured by registering the prepared surface (P) or an artificial abutment directly in the mouth or from a model e.g. in plaster by a three dimensional mechanical or optical method. The registered surface is reproduced in an enlarged size (L) e.g. with a computer controlled milling machine. The enlargement is calculated from the shrinkage of the ceramic material during sintering to full density. When calculating the shape of  $K_1$  the gap for cement is considered. It is important that the preparation border S respectively  $S_1$  are evident. Below the preparation border  $S_1$  between  $S_1$  and the bottom R the body ( $K_1$ ) is given such a shape that its surfaces converge to the occlusal part of the preparation. At the bottom (R) the outer surface can be e.g. cylindrical. The body ( $K_1$ ) can be manufactured in e.g. metallic material, graphite, polymers et cetera.  $K_1$  will have such a size that the inner surface of the green body (the impression of L) after shrinkage during sintering to full density receives the inner surface I, which has desired fit against the prepared tooth surface (P) or to an artificial abutment. The surface (L) of the body  $K_1$  is manufactured with a computer controlled milling machine, which enlarges the registered tooth surface, will after compacting the powder against this surface (L) and sintering to full density give the inner shape of the core (I). During compaction the outer surface (Y) of the core is formed as follows: A body ( $K_2$ ), which is shown in Fig.

3 is milled with a computer controlled milling machine from registered data from the prepared surface (P) of the registered tooth or the surface of the artificial abutment. This body ( $K_2$ ) is enlarged considering the sintering shrinkage in the same way as the body  $K_1$  and with an additional material from the preparation border or just below.  $K_2$  contains the outer surface Z. The outer surface Z can be formed by forming a coping in any easily moldable material e.g. wax or a material, which easily can be formed against the body  $K_1$ . The outer surface (Z) of this second body ( $K_2$ ) or ( $K_1$ ) with a coping in e.g. wax is used to form the outer shape (Y) of the core. An impression (X) is made from the body ( $K_2$ ), or  $K_1$  with a coping in e.g. wax in some viscous elastic material e.g. a silicone. The compaction of the powder can be made with tool according to Fig. 3. This tool contains the impression X.  $K_1$  fits into X from the bottom (R) to the preparation border S. Between the surface (L) of  $K_1$  and X there is a cavity M. The impression X has such a shape as to fit into a body E, which can contain a viscous elastic material. The body E is placed into a tube (F), which is put on G, which is a part of  $G_1$ . The cylinder (H) with the same diameter as G is put into the tube (F) from the top. Between H and E containing X is a lid (J) placed in the same material as E.

The manufacture of an individual core to a tooth crown can be made in the following way: The pressing tool is put together with the tube F on the cylinder G. E with X is put into the tube F. Ready to press powder is filled into the cavity M and the body  $K_1$  is fit into X.  $K_1$  fits into the impression X from the preparation border  $S_1$  or just below and to the bottom R of the body  $K_1$ . Finally, the lid J and the cylinder H are placed and the whole tool according to Fig. 3 is put into a press e.g. a uniaxial hydraulic press. During the compaction of the powder the cylinder H is pressed with the force  $P_k$  in the tube F against the cylinder G in contact with the lid J and the powder is compacted against the body  $K_1$ . After the compaction H, J and  $K_1$  are removed and the compacted shell, which in some cases can be attached to  $K_1$ . K must not contain any undercuts. The wall thickness of the green body is determined by the amount of powder put into M. After the pressing the green body is adjusted at the preparation border ( $S_1$ ) and the wall thickness is controlled and adjusted before the sintering to full density. The wall thickness can be 0.5 mm, however, on certain places wall thicknesses >0.5 mm can be needed in order to strengthen marginal ridges or for replacement of removed fillings. After sintering to full density the core (B) is adjusted against the preparation border (S) of the plaster model in order to fit the surface I of the core against the surface P of the prepared tooth or against the artificial abutment. Finally dental porcelain can be fired to the core for the manufacture of a tooth crown.

A veneer can be manufactured in the same way

as above.

A core (B) of an inlay can also be manufactured by registering the surface (P) prepared for an inlay by a three dimensional mechanical or optical method. The registered tooth surface is reproduced in an enlarged size in a metal, graphite or a polymer e.g. with a computer controlled milling machine, which enlarges the preparation. The enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and with a reduction for the cement. An impression (X) (Fig. 3) can be manufactured in the same way, as for a core of a tooth crown. Before the manufacturing of the impression X for an inlay the enlarged preparation is overfilled with e.g. wax. This enlarged model with the filled preparation cavity is used for the manufacture of the impression X in some viscous elastic material e.g. a silicone. This impression is placed in a press in the same way as described in Fig. 3 after the ceramic powder has been put in the cavity between the enlarged model and the impression X. After the compaction the green body is removed. In order to be able to remove the green body without destroying it, the preparation must not contain any undercuts. The green body is adjusted against the preparation border and space can be given if dental porcelain will be fired to the outer surfaces of the inlay, that means the surfaces which are not cemented against the prepared surfaces of the tooth. After the sintering of the core some adjustment by grinding or polishing can be needed.

When manufacturing a bridge it is important to maintain the mutual relationship after the enlargement. A bridge can be manufactured by starting with the registration of the surfaces of the prepared tooth and the soft tissue in between by a three dimensional mechanical or optical method. It is important to register the mutual relationship of the supporting teeth which can be done in the following way. An impression is made with conventional impression technique e.g. with a silicone impression material. This impression is cast in e.g. plaster. From this model or directly in the mouth the prepared teeth and the jaw in between is registered by a three dimensional mechanical or optical method. The prepared teeth and the tooth free jaw in between are reproduced in an enlarged size with e.g. a computer controlled milling machine. The enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and with an additional space for the cement. The material in the enlarged models can be e.g. graphite, metal or a polymer.

An enlarged model which considers the whole situation can also be made in the following way. An impression as shown in Fig. 4 is made from the supporting teeth and the tissue in between with a conventional impression technique e.g. with an impression material in e.g. a silicone material (A). Fig. 4 shows a cross section of an impression. The tubes b,

and  $b_2$  are pressed into the impression material (a). In order not to deform the impression of the preparations that part of the tubes pressed into the impression material can e.g. have a chamfered edge. The tubes can also be fixed to the impression with e.g. sticky wax. The tubes  $b_1$  and  $b_2$  can e.g. have elliptic or circular cross section with grooves ( $q_1$  and  $q_2$ ) in the longitudinal axis in the internal surfaces of the tubes, and a step  $e_1$ - $e_2$ , is clear from a cross section parallel with the longitudinal axes. The tubes  $b_1$  and  $b_2$  have parallel longitudinal axes and surround the impressions ( $c_1$  and  $c_2$ ) of the preparations of the supporting teeth in the impression material (a). The tubes  $b_1$  and  $b_2$  are fixed to each other with  $b_3$ . The impressions ( $c_1$  and  $c_2$ ) are poured out in e.g. plaster, which gives the models ( $n_1$  and  $n_2$ ) shown in Fig. 4. The models  $n_1$  and  $n_2$  are registered with a three dimensional mechanical or optical method and are reproduced in an enlarged size with e.g. a computer controlled milling machine. The enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and with an additional space for the cement above the preparation border ( $S_1$ ) of the models  $N_1$  and  $N_2$ . The material of  $N_1$  and  $N_2$  can be e.g. metallic material, graphite or a polymer. These enlarged models ( $N_1$  and  $N_2$ ) are put into a fixture  $f$  as shown in Fig. 5. The fixture  $f$  contains a plate in e.g. a metal, which has two holes  $g_1$  and  $g_2$ . These holes have a geometry, which is uniform with the internal surfaces of the tubes  $b_1$  and  $b_2$  and enlarged with the same enlargement factor considering the sintering shrinkage for the current ceramic powder. The distance ( $H$ ) between the longitudinal axes of the holes is enlarged considering the sintering shrinkage of the ceramic material. By placing the enlarged models  $N_1$  and  $N_2$  in the fixture  $f$  an enlarged model of the prepared supporting teeth and their mutual relationship is made. The step  $E_1$ - $E_2$  and the grooves  $Q_1$  and  $Q_2$  and the distance ( $H$ ) give the mutual relationship of the enlarged preparations. The manufacturing of the tool for compacting the ceramic powder to the bridge is made in a similar way as is shown in Fig. 3. An impression  $X$  has to be made which gives space for powder to a beam which connects the copings, which after the compaction will fit the enlarged preparations  $N_1$  and  $N_2$ . Fig. 6 is an outline figure of the impression  $X$ . In Fig. 6 the models  $N_1$  and  $N_2$  put in the fixture  $f$  are placed in the impression  $X$ , manufactured in the same way as has been described for cores of single tooth crowns. In the empty space  $M_1$ , which surrounds  $N_1$  and  $N_2$ , ceramic powder is placed and the tool is put in a pressing tool according to Fig. 3 and a compacting pressure  $P_x$  is applied. The ceramic powder will be compacted against  $N_1$  and  $N_2$  and against the part of the fixture, which is situated between  $N_1$  and  $N_2$ . The green body is removed and the copings are adjusted at the preparation border and where the wall thickness needs reduction. The beam can be

formed with e.g. a milling cutter in a hand piece of a dental technician in order to give it a suitable form as a substructure of pontics. The core is sintered to full density. After the sintering some adjustment can be needed before the firing of dental porcelain to the core to have a bridge according to Fig. 2.

The manufacturing of a bridge the mutual relationship of the supporting teeth can be maintained after the enlargement in many other ways e.g. before the impression (a) is cast some markers are placed in the impression in such a way that they give impressions in the different parts (the supporting teeth and the jaw in between) into which the plaster model will be divided by sawing. The impressions of the markers in combination with enlarged markers can be used to have the mutual relationship of the supporting teeth after the enlargement.

A bridge can also be manufactured, which is based on supporting teeth with preparations for a veneer on the buccal surface or a preparation on the lingual surface for a lingual plate. The manufacture of such a bridge can be made in the same way as has been described for a bridge with supporting teeth prepared for full crowns.

A bridge can also be made for supporting teeth prepared for inlays. In order to have the mutual relationship between the supporting teeth in the enlarged model considering the sintering shrinkage, the manufacture of compaction tool and the compaction are made in the same way as described for a bridge with supporting teeth prepared for full crowns. The supporting teeth can have different types of preparations.

A bridge based on supporting teeth prepared for inlays can also be made in densely sintered, ceramic material by starting from e.g. a plaster model of the prepared teeth and the jaw between. A beam can be made by using a light hardened polymer filled into the inlay preparations and connecting the preparations of the bridge. Before the hardening of the polymer it is given such a shape that the inlays and the beam between have the desired form. After the light hardening of the polymer bridge it is removed and is registered by a three dimensional mechanical or optical method and reproduced in an enlarged size to a green body or a presintered ceramic body with e.g. a computer controlled milling machine. The enlargement is calculated from the shrinkage of the ceramic material during sintering to full density.

Another way of manufacturing a densely sintered shell, which after sintering to full density fits to a prepared tooth, is to make an impression of the enlarged body  $K_1$ , considering the sintering shrinkage and an additional space for the cement according to Fig. 3. This impression is cast in plaster and a model  $K_2$  in plaster is obtained from  $K_1$ . An impression ( $X$ ) is made according to Fig. 3. Against  $K_2$  ceramic powder is compacted with e.g. the compaction tool described in

Fig. 3. The green body is presintered on the plaster model. Alumina is presintered at 800°C-1100°C. During the presintering water is released from the plaster, which shrinks about 15%. The ceramic material shrinks much less and the presintered core can easily be removed, adjusted and sintered to full density.

Further, another way of manufacturing a densely sintered shell, which after sintering to full density fits on a prepared tooth, is to make a slurry of ceramic powder mixed and ground under wet conditions with water or an inorganic solvent (e.g. alcohols) as grinding liquid. To the ceramic slurry lubricants or other organic binders are added. On the enlarged plaster model  $K_2$  of the prepared tooth the slurry of the ceramic powder is placed in some way e.g. with a brush from the preparation border ( $S_1$ ) to the top (T). The plaster model of  $K_1$  ( $K_2$ ) can also be dipped into a slurry of the ceramic powder. In order to have an optimal compaction of the powder, a suction cup can be applied to the bottom surface (R) and by the suction cup a negative pressure is applied during the dipping of the body  $K_2$  into the slurry as described in the Swedish patent application no. 9004134-4. The ceramic particles will be packed against the plaster model, when this model absorbs the water from the slurry. In this way the ceramic powder is compacted against the plaster model and the body compacted in this way can be adjusted at the preparation border  $S_1$  and adjusted to desired shape and shell thickness of the core. The green body is presintered on the plaster model. The presintered body will be too big for the plaster model and can be removed for any adjustment and sintering to full density. Instead of plaster other porous materials can be used provided that they can be used as sintering support during the presintering.

Bridges can be manufactured with above described slip casting method by making an impression from  $N_1$  and  $N_2$  in the fixture f (Fig. 5) and cast in e.g. plaster. Before the impression is made a support for the slurry to make the substructure for the pontics is built up with e.g. wax on the fixture between  $N_1$  and  $N_2$ . An impression is made of the fixture with the support ( $N_1$  and  $N_2$ ) for the pontics, which is cast in plaster. The plaster model is fixed to a plate in some ceramic material and is divided into three parts ( $N_1$ , pontic and  $N_2$ ). The three parts have the same mutual relationship as before the separation. Against the plaster model a slurry is placed in the same manner as was described for cores for single tooth crowns. The separated and fixed plaster model with the ceramic slurry is presintered and the presintered bridge core can, if needed, be adjusted before the sintering to full density.

Another way of manufacturing a core of a bridge is to compact ceramic powder with a tool shown in Fig. 6 against  $N_1$  and  $N_2$  in the fixture f according to Fig. 5 or against a plaster model according to Fig. 5 fixed and separated into three parts. The tool is placed in

a compaction tool similar to that shown in Fig. 3 after the ceramic powder has been placed into  $M_1$ . The green body manufactured in this way is adjusted before the presintering. After the presintering the body can have any adjustment before the sintering to full density in a known way.

## Claims

1. Method of manufacturing artificial tooth restorations comprising a ceramic densely sintered, high strength individual core (B) with dental porcelain (A) by powder metallurgical manufacturing methods characterized in that the inner surface (I) of the core (B), which will fit against one or more prepared tooth surfaces (P) or artificial abutments are manufactured by forming a ceramic powder mixture against a surface of a body at which this mentioned surface is manufactured by registering the surfaces of the prepared teeth or artificial abutments and their mutual relationship with a three dimensional optical or mechanical reading method directly in the mouth or on a model in e.g. plaster after which the registered surfaces are reproduced in an enlarged size e.g. with a computer controlled milling machine at which the enlargement is calculated from the shrinkage of the ceramic material during sintering to full density and considering the gap for cement.
2. Method according to claim 1 characterized in that the outer surface Y of the core is dry pressed close to desired size against the enlarged preparations with the help of an impression in some viscous elastic material.
3. Method according to claims 1 and 2 characterized in that the core is made by a dry pressing against a e.g. plaster model of the enlarged preparations, after which the core is presintered on the plaster model.
4. Method according to claim 1 characterized in that the core is manufactured by slip casting against e.g. a plaster model of the enlarged preparations, after which the core is presintered on the plaster model.
5. Method according to claims 1, 2, 3 and 4 characterized in that the core consists of high strength densely sintered, ceramic material with a relative density of > 99%.
6. Method according to claim 5 characterized in that the ceramic material in the core is based on one or more of the oxides  $Al_2O_3$ ,  $TiO_2$ ,  $MgO$ ,  $ZrO_2$

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or  $\text{ZrO}_2$  with up to 25 mole%  $\text{Y}_2\text{O}_3$  or  $\text{MgO}$ .

7. Method according to claims 5 and 6 characterized in that the core material also comprises whiskers and/or particles of  $\text{SiC}$ ,  $\text{TiN}$ ,  $\text{ZrO}_2$  and/or  $\text{ZrN}$ .

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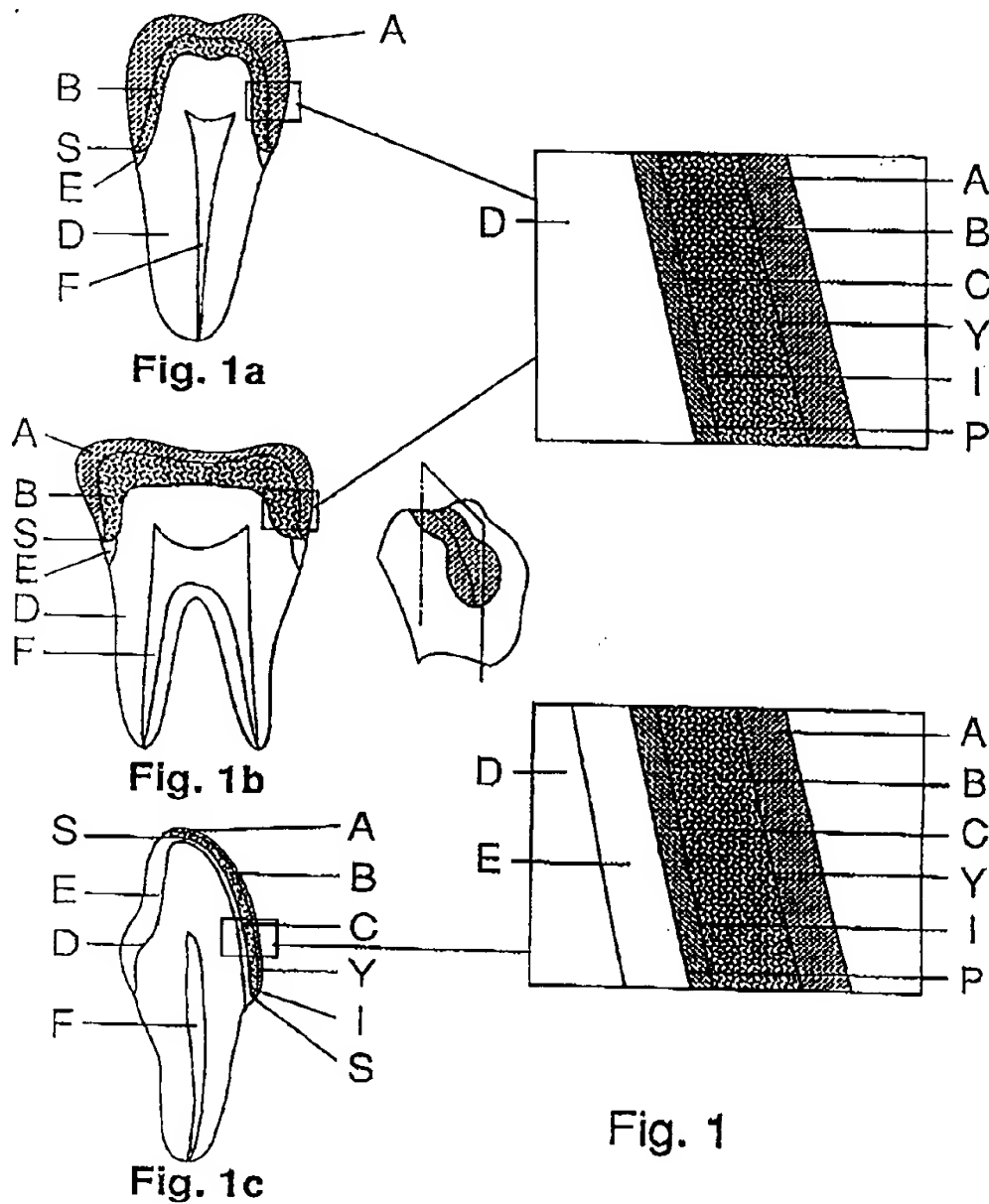
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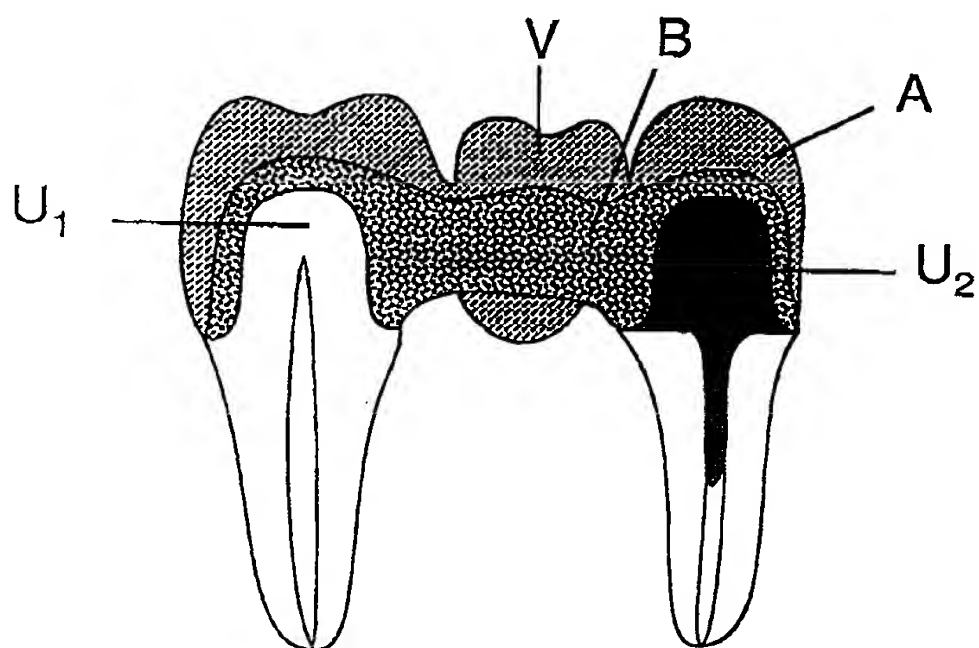


Fig. 2

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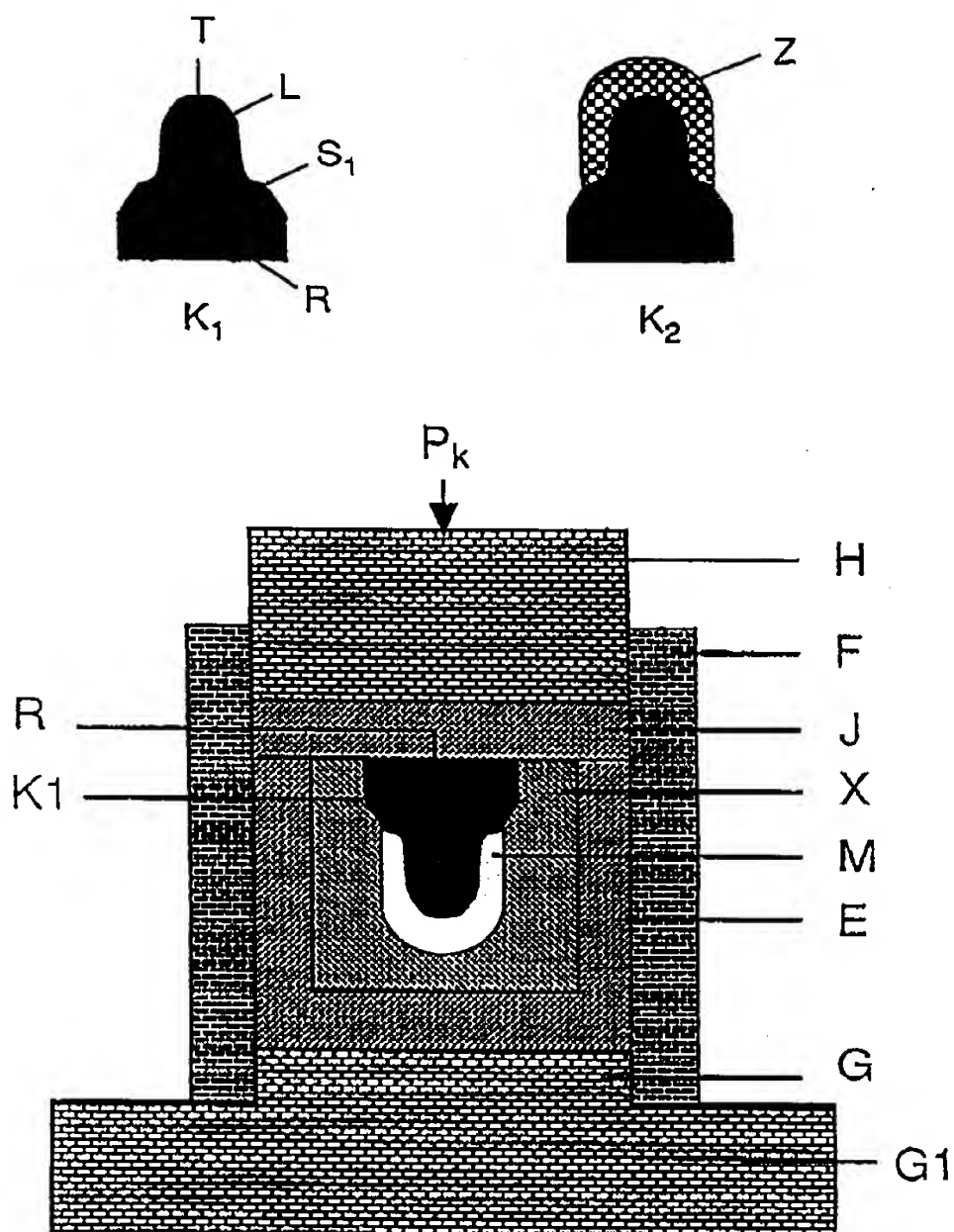


Fig. 3

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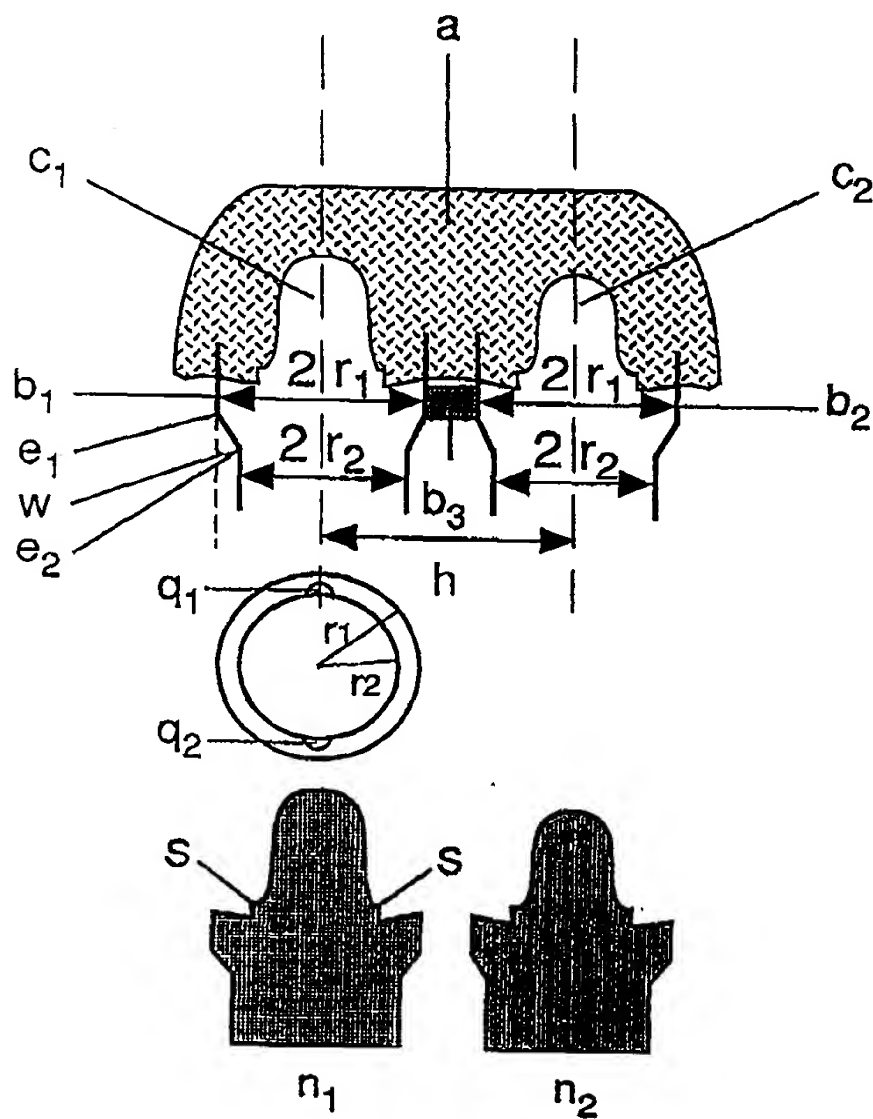


Fig. 4

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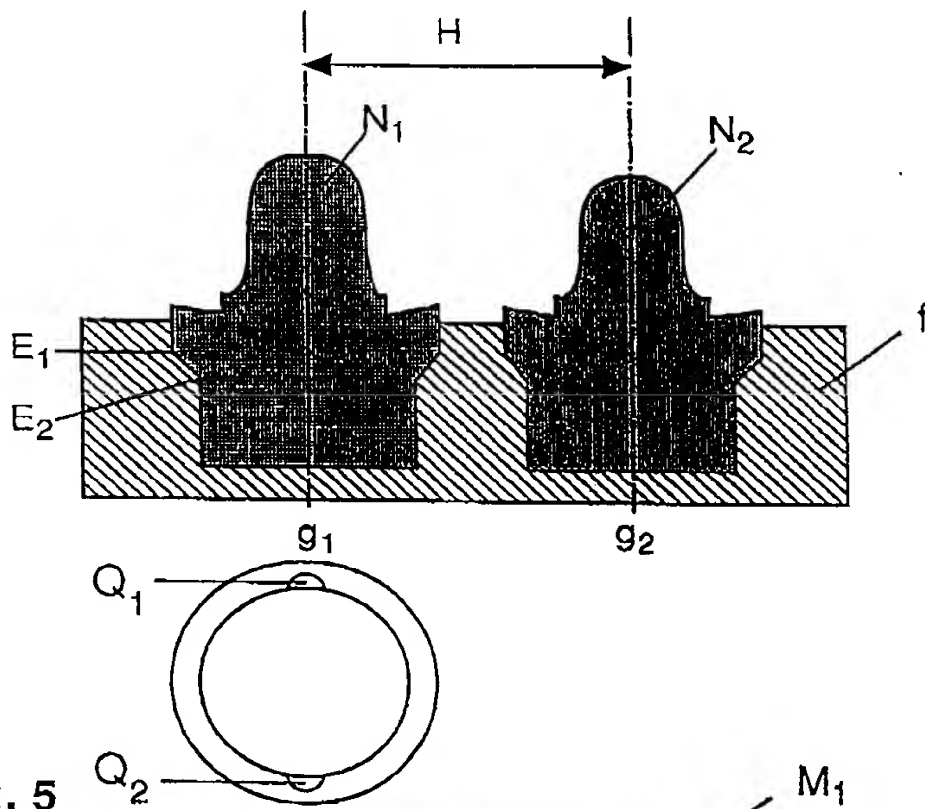


Fig. 5

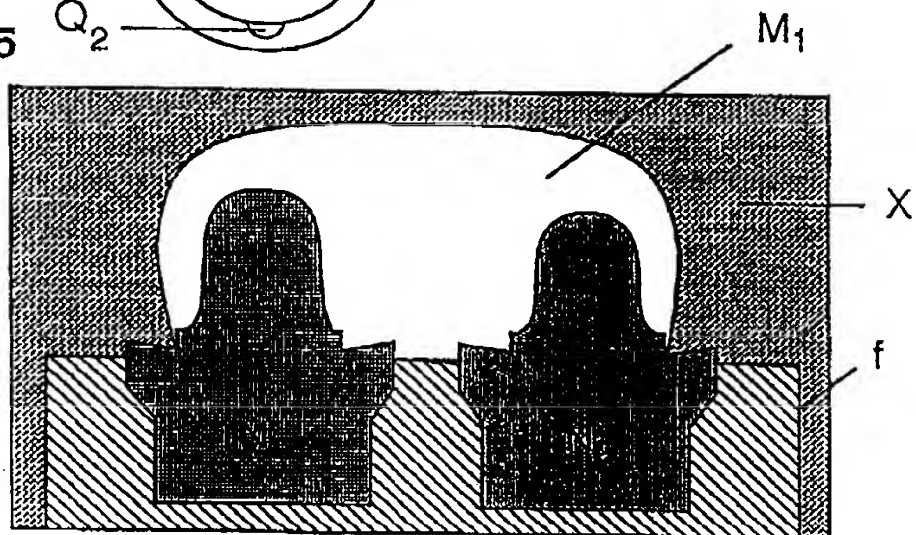


Fig. 6